

Appendix B USACE Navigation Case Histories

The following case histories represent examples of planned or executed U.S. Army Corps of Engineers projects using offsite prefabrication construction technology. These case histories should not be viewed as the only ways to employ offsite prefabrication technology, but rather they should be studied for the lessons learned from them. Applicable figures in Appendix C are referenced. The following non-SI units of measurement used in this appendix may be converted to SI units as follows: to convert feet to meters, multiply by 0.3048; to convert inches to millimeters, multiply by 25.4; to convert miles to kilometers, multiply by 1.609344; and to convert tons to tonnes, multiply by 0.9071847.

B-1. Braddock Dam

a. The new Braddock Dam (Figures C-10 through C-15) was designed to replace an existing fixed-crest dam on the Monongahela River near Pittsburgh, Pennsylvania. The new gated dam is approximately 750 ft long; 600 ft of the structure comprises one fixed weir bay, one water quality gate bay, and three tainter gate bays. A closure weir comprising cellular sheet-pile cells and a concrete weir complete the remainder of the dam structure. The signature feature of this project is the offsite prefabrication of two large concrete dam segments that were floated to the project site and set down onto preinstalled foundations. Segments were fabricated in a two-level casting basin built in Leetsdale, Pennsylvania, along the Ohio River about 27 miles downstream of the actual Braddock project site. Each segment was launched by flooding the casting basin, then towing each segment to a location near the site for final outfitting. Following this step, the segments were delivered to the site, immersed, and filled with concrete. Another part of the project involved the left closure weir, which was completed in the wet. Placement of downstream scour protection and upstream stone training dikes and removal of the existing fixed crest dam complete the project. Design of the dam was completed in November 1998. Construction began in August 1999. The new dam became fully operable in the fall of 2003. Completion of the entire project is scheduled for spring 2004.

b. Some of the more significant engineering challenges on the project include the following:

(1) Design and development of a two-level casting basin and launch facility for the two prefabricated floating dam segments.

(2) Design and construction of two concrete shells, one 333 ft long by 104 ft wide, another 265 ft long by 105 ft wide, with sufficient strength for launch, transport, and immersion while maintaining a maximum draft at float-out of only 10 ft. Over 400 precast concrete panels were manufactured and erected to form the exterior and internal diaphragm walls of the segments. Bottom and top slabs and the intersections of panels were cast in place. To control segment weight and draft, both lightweight and normal-weight concrete was used. The 11,000-ton Segment 1, which measured 333 ft by 104 ft, was launched on July 10, 2001, and towed to the project site on July 26, 2001. The second and smaller 9,000-ton segment, measuring 265 ft by 104 ft, was completed and towed to the project site in February 2002.

(3) Developing a transportation, positioning, and immersion plan that can safely accommodate a 500-year flood at any time with only a 48-hr notice.

(4) Developing a positioning and alignment system for landing the segments in a 3-ft/sec current and meet a tolerance of $\pm 1/4$ -in. vertically and ± 2 in. horizontally. Following outfitting and preparations for immersion, each segment was transported from the outfitting area, about 1-1/2 miles downstream, to the damsite for set-down. After initial positioning for set-down was achieved using towboats, each segment was attached to mooring piles with winches and cables for final positioning. Using a designed ballasting

sequence, water was added to the hollow compartments of the segment in a controlled manner to slowly lower it down onto the drilled shaft foundation. After each segment was set down, they were joined at a common pier with a grouted post-tensioned connection. All alignment tolerances were met. Segment 1 was set down onto its foundation system in December 2001. Segment 2 was set down in June 2002.

(5) Developing designs and construction procedures for a drilled shaft foundation system that will assure accurate location of all drilled shafts to within ± 6 in. horizontally and ± 2 in. vertically. The basic dam foundation system comprises upstream and downstream cutoff walls, a graded gravel base, and a system of drill shafts. Eighty-nine reinforced concrete drilled shafts serve as the foundation for the new dam. Each shaft measures 78 in. in diameter and about 40 ft in depth with 15 to 20 ft of each shaft drilled into the bedrock. A series of steel bearing piles form the foundations for the dam tailrace area. All foundation work was completed by the end of August 2001.

(6) Developing unique design mixes for underwater concrete/grouts for filling the dam underbase and infilling the concrete dam segments. Mixes must be acceptable to control thermal cracking of the precast dam segments. Some mixes must flow up to 25 ft without segregation in test conditions.

(7) Concurrent construction at the prefabrication site and project site. While the two float-in segments were being fabricated offsite, work continued concurrently at the Braddock project site to complete the dam foundation system.

(8) Design and construction of tailrace in the wet using precast concrete panels and a program of underwater concrete infill placement. Thirty-one panels, weighing up to 65 tons each, were match cast near the project site for the dam tailrace. Each panel was designed and manufactured to interlock with the next adjoining tailrace panel and connect to a specially designed groove that was cast into the downstream edge of the float-in dam segments. The panels will be supported along their downstream edge by the pipe piles, which were incorporated into the design of the downstream cutoff wall. Panels were installed by cranes mounted on floating plant using a guide frame to assist in accurate setting of the panels. The void beneath each tailrace panel was then filled with tremie concrete to create a mass concrete tailrace section that is supported by the previously installed H-pile foundation system.

(9) Fabrication and in-the-wet installation of tainter gates in one piece. The new steel tainter gates of the dam were installed in four of the five gate bays. Each tainter gate is 110 ft long. Three of the four gates are standard tainter gates at 21 ft high while the remaining shorter water quality gate is 12 ft high. All gates were fabricated, shipped, and installed in one piece. Erectors along with engineers evaluated this approach to assure that erection sequences, equipment, rigging, and other necessary measures were properly designed and addressed so these structures were safely and accurately installed.

(10) The upper 40 ft of the five dam piers were completed above the waterline in the dry with conventional jump forming systems. Extension of the concrete piers and other features of work such as tainter gates and footbridges were completed by crews using equipment mounted on floating plant.

(11) Following completion of the new dam, the existing fixed-crest concrete dam that is located about 600 ft downstream was completely removed to the riverbed. The demolished concrete materials were placed in downstream locations as fish habitat.

c. For additional information contact the U.S. Army Corps of Engineers, Pittsburgh District, William S. Moorhead Federal Building, Pittsburgh, PA 15222.

B-2. Chicago Harbor Lock

a. The sector gates and gate bays were rehabilitated in the wet for Chicago Lock, Illinois, in 1996. This work was conducted at night while traffic used the lock during the day. The work included the provision of new bulkhead slots, new gate sill surfaces, new pressure relief holes, and temporary and permanent culvert closures.

b. Significant aspects of this work included the following:

(1) The work for the new bulkhead slots was conducted within blister cofferdams attached to the lock walls.

(2) The work for the new gate sill surfaces was conducted using precast concrete panels placed underwater and underbase grouting with special washout-resistant cement grout.

(3) New pressure-relief holes were provided in the bottom of the gate bays between the maintenance bulkheads to prevent uplift problems when the bays are dewatered to work on the sector gates.

This work was completed successfully with minimal impact on traffic through the lock.

c. For additional information contact the U.S. Army Corps of Engineers, Chicago District, 111 North Canal Street, Chicago, IL 60606.

B-3. Inner Harbor Navigation Canal Lock

a. Innovative construction of a concrete float-in lock for the Inner Harbor Navigation Canal (IHNC) lock replacement project has been authorized. The replacement lock will be located on the canal about 0.5 mile north of the existing lock. The innovative float-in concept was selected to address the space restrictions imposed by construction within an urban site of historic buildings, to permit continuous navigation within the canal, and to reduce costs. The lock is located within the City of New Orleans on the Gulf Inner Coastal Waterway (GIWW) and connects the Mississippi River with major navigation routes and the Port of New Orleans. Two lock configurations were considered: a recommended 1,200-ft by 110-ft by 36-ft ship lock and a baseline 900-ft by 110-ft by 22-ft barge lock. The ship lock was selected; the local sponsor will pay the difference for the larger ship lock. The Feasibility Study was completed in 1996 and the project authorized in 1998. As of August 2003, the detailed lock design was 30 percent complete, and it is anticipated that plans and specifications will be completed in late 2006.

b. The structure will be a pile-founded U-frame constructed in five modules. The modules will be supported independently of one another such that no load transfers between modules. The piles are 48-in.-diameter steel pipe piles. There will be two gatebay modules and three chamber modules. The module base and lower walls will be a hollow concrete shell similar to a concrete barge. Upper wall design is incomplete; designers are investigating a precast shell wall and a cast-in-place mass concrete wall. The lock filling system is unique in that sector gates will be used in lieu of the more typical miter gates. The sector gates were economical in this project because they can operate against the reverse head that exists a small percentage of the year. Initially, miter gates were included in the design; however, four sets were needed because of the reverse head. A sidewall culvert filling and emptying shall be used to control the water levels. Eliminating the culvert system by using the sector gate end filling was considered. Model tests done at the U.S. Army Engineer Research and Development Center indicated that end filling would take considerably longer than the culvert system.

c. The sequencing of construction would generally be as follows:

(1) The canal will be widened to provide a temporary bypass navigation channel, and temporary vessel impact protection structures will be built.

(2) A graving site (prefabrication facility) will be constructed on the waterway system within a few miles of the site.

(3) Float-in precast concrete segments approximately 400 ft long will be partially completed within the graving site.

(4) The lock site will be prepared by dredging, installing piles, and preparing set-down pads.

(5) Each segment will then be moved to the installation site and ballasted to the bottom. Tremie concrete will be placed to join the structure and the pile foundation.

(6) Second-stage construction will be performed at the lock site after the base section is set onto the predriven piles; there will be no intermediate staging area. The contractor may elect to build a tall section at the graving site prior to float-out or construct a braced cofferdam above the lower walls. The available 35 ft of draft permits heavier float-out sections than what can be considered for most inland waterways. For this reason, low-density concrete was not used.

(7) The sector gates will be fabricated offsite and installed after the module upper walls are complete.

(8) The new lock will be tied to the levees, the bypass channel will be backfilled, and the existing lock will be removed.

B-4. Olmsted Locks–Floating Approach Walls

a. The walls (Figure C-17) consist of four pontoons ranging in length from 159 to 1,667 ft, as well as a single fixed wall (the lower land wall), which is 567 ft long. After the design of the floating walls had begun, a meeting with representatives of the towing industry resulted in the addition of the short (159 ft long) lower middle wall, which replaces the guard cell previously planned. The pontoons vary in width from 38 to 42 ft, and are typically 14 ft 6 in. high with parapet walls 3 ft 6 in. high. Each of the longer pontoons is to be constructed in segments with length in the 300- to 400-ft range. The pontoons have isolated compartments every 20 ft, and each pontoon is restrained laterally by a pylon at each end. The pylons are 13 ft square and constructed of precast concrete supported on concrete-filled drilled shafts jacketed in steel. At the lock end of the pontoons, the pylons are part of the lock monoliths. There is no mechanical connection between the pontoons and the pylons; however, electric power transmission to the pontoons is accomplished by the use of motorized cable reels. High-mast lighting is provided for all of the walls. Life rescue boats (which will be lowered into the water with jib cranes) are provided on both the upper middle wall and lower middle wall. Access is provided to all portions of all structures with stainless steel ladders. Fall protection is provided at each ladder in accordance with EM 385-1-1.

b. Construction of the approach walls will occur at three separate locations. The drilled shafts for the nose piers, pylons, and lower land wall will all be constructed at the Olmsted site. The precast elements of the nose piers, pylons, and lower wall were precast at an existing precast plant in Mt. Vernon, Indiana, on the Ohio River. The pontoons will be cast in a graving dock, to be constructed on Tennessee River bottomland near the junction with the Ohio River at Paducah, Kentucky.

c. Once the pontoons have been cast and cured, they will be post-tensioned. The next step is for the pontoons to be floated out of their casting beds. The concrete slabs that compose the casting beds will be coated with a special bond breaker that will assure that the pontoon bottom slabs will cleanly separate from the casting beds. The pontoons will be pushed to the site with towboats and moored until the

integration process begins. The contractor will use the completed Olmsted Locks chambers as a quiet water location to perform the critical integration of the individual pontoons into the long floating walls. The pontoon segments will be integrated with high-strength, 3-in.-diameter bolts, which are post-tensioned. After post-tensioning of the bolts, the bolt sleeves and the space between the pontoon end walls will be grouted. After the pontoons have been integrated, they will be installed in their final position between the pylons using a combination of towboats, cables, and winches.

d. The construction contract for the Olmsted Approach Walls was awarded on August 26, 1999, for a total cost of \$98,980,610.00. The duration of the construction contract is 39 months.

B-5. Olmsted Dam

a. Construction of Olmsted Dam (Figures C-4, C-5, C-16) will start from the right (Illinois) side of the river adjacent to the lock and will incrementally advance toward the left (Kentucky) side of the river. Construction will consist of the following:

- (1) A 20-ft-long isolation structure between the lock and tainter gate section.
- (2) A 5-bay, 564-ft-long tainter gate section.
- (3) A 15-ft-long isolation structure between the tainter gate structure and the right boat abutment.
- (4) A 55-ft-long right boat abutment.
- (5) A 1,400-ft-long wicket gate navigable pass.
- (6) A small isolation structure joint between the navigable pass and the left boat abutment.
- (7) A 207-ft-long left boat abutment.
- (8) A three-cell cellular fixed weir.

b. During construction, the over-water work is scheduled to be performed from mid-June to November, while fabrication of precast concrete segments in the precast yard is planned to be conducted all year round. The entire construction is scheduled for completion within 2200 days after award of contract. The construction period is divided into five phases. The Phase 1 construction activities are mobilization, establishment of a precast yard, and fabrication of the initial tainter gate section precast concrete segments and steel tainter gate section. In Phase 2, the first 2-1/2 tainter gate bays will be constructed. The last 2-1/2 tainter gate bays will be constructed in Phase 3. The right boat abutment and half of the navigable pass will be constructed in Phase 4. The rest of the navigable pass, the left boat abutment, and fixed weir not constructed under the lock contract will be built in Phase 5.

c. There are six main stages that involve most major construction activities:

- (1) Prefabrication of concrete segments, up to 4,200 tons, in a precast yard.
- (2) Riverbed preparation and construction of the pipe pile foundation and sheet pile walls.
- (3) Placement of precast concrete modules with a heavy-lift crane barge and riprap placement.
- (4) Onsite tremie concrete construction activities.

(5) Installation of tainter gates, access bridges, mechanical and electrical devices.

(6) Navigation control.

d. Some of the more significant engineering challenges on the project include the following:

(1) Developing an offsite prefabrication facility that can handle up to 4,200-ton segments.

(2) Construction in an uncontrolled river environment with a sandy bottom and environmentally sensitive species nearby.

(3) Design of the dam to resist a Maximum Design Earthquake with a horizontal zero period acceleration of approximately 0.85g with a 1,000-year recurrence period.

(4) Developing an efficient construction plan using large floating equipment for heavy lifting of shell segments, pile driving, screeding, and concrete production.

(5) Developing designs and construction procedures for a driven pile foundation system that will assure pile location tolerances of ± 3 in. horizontally and ± 4 in. vertically.

(6) Developing unique design mixes for underwater concrete for infilling the dam segments. Mixes must be acceptable to control thermal cracking of the precast dam segments. Some mixes must flow over 25 ft without segregation.

e. Design of the dam is completed. A request for proposals for the construction contract award was originally issued in the fall of 2002 under a fixed price contract. Although interest was expressed by contractors, especially with this “world class” project, there were many concerns associated with risk on the part of the contractors. This risk included variability in river and weather conditions that could impact the schedule in ways that are difficult to overcome without substantial risk to the contractor. Also, the long-term, large project with variable world conditions that could affect supply and demand was considered a risk factor. In general, firm fixed-price ways of dealing with changes were perceived as problematic on the part of some potential bidders because of their perceived notion that the Government believes that the contractor is responsible because the firm bid the completed job. The use of construction methods that included some unfamiliar details such as coordinating very heavy lifts were viewed with concern. Virtually all contractors indicated an unwillingness to take on any design responsibility for finished project features. Another factor that influenced the potential bidding pool was the size, specialization, and complexity of the river work for this project, which generally resulted in a combination of several contractors into joint ventures, which further limited potential competition. Although an amendment was issued that moderated the concerns by potential bidders, it was still questionable that there would be bidders because of the high level of concern that remained in the technical, contractual (delay), and contract administration areas. Many of these concerns would have existed for any method of constructing this project, not just the heavy lift-in method. (In fact, several large river construction projects within the Corps have received only a small number of bids or proposals in recent years.) Discussions then turned more specifically to the type of contracting for the work effort. Consideration was given to splitting the contract into multiple smaller ones, but potential impact of one contractor affecting another was judged worse rather than better. A search of requirements used nationwide for somewhat similar large-scale, complex, and potentially variable projects led to the conclusion that risk could be better managed with a cost-reimbursable type contract. This type of contract affords greater flexibility for both the Government and contractor to overcome unusual conditions. It also requires a higher degree of involvement and shared decision-making by both parties as well as increased administrative oversight. This change has been made and the solicitation has been reissued. Bidder interest has increased substantially to date. Corps expertise outside the Louisville District has reviewed and commented on revised documents. Cost Reimbursement training is scheduled for the implementation

team. Utilization of this type of contracting is not new within the Corps, but it is for such a large civil works project. Lessons learned with this type of contract and teamwork that is developed should be useful for future projects of a similar nature.

f. For additional information contact the U.S. Army Corps of Engineers, Louisville District, 600 Dr. Martin Luther King Jr. Place, Louisville, KY 40201.

B-6. Ohio River Main Stem Study

a. General. Float-in construction techniques are proposed for several lock elements in the Ohio River Main Stem Systems Study (Figure C-20). These elements include a middle wall intake monolith, lower land wall and miter gate monoliths, cross-over culverts, and the upper and lower floating approach walls.

b. Float-in monoliths:

(1) The first stage is to construct or use an offsite facility for construction of the base portions of the float-in structure. This offsite facility could be either a submersible barge or a dry dock facility. Either the dry dock facility would have to be constructed, or a previously developed site could be used. The submersible barge involves construction of the floating raft base on the deck of a barge that is specially equipped to be submersible. The base for the float-in element would be constructed, and then the barge would be moved into an area with sufficient water depth and sunk. The float-in base would then be moved to the site for the next phase of work. For the dry dock operation, the float-in base is constructed in the dry dock. Once it is completed, the dock is flooded and the base is floated to the site. For both the submersible barge idea and dry dock operation, the base can be constructed only to the level for which the allowable draft is reached and floating stability requirements are met.

(2) The second stage involves the construction of an onsite temporary workstation that will be required for the deep-draft construction stages of the float-in structures. First, a construction access road will be required to connect the existing road to the onsite workstation. The onsite workstation will be composed of a dredged area and channel, a work platform, and mooring dolphins. Once this is complete, the float-in bases constructed offsite in the first stage are floated to the onsite workstation for placement of additional concrete. Once they are at the onsite workstation, construction of the shell of the monolith is continued. It is important to note that the onsite workstation is far enough away from the existing lock chambers not to adversely affect existing navigation traffic during construction of the float-in structures.

(3) The third stage involves floating the shell structure from the onsite workstation to its final position. This will involve some preliminary in-water excavation and bedding preparation to ensure that the base is adequate to accept the float-in structure. The preparation will consist of underwater removal of the existing weathered rock, cleaning by airlift or similar method, and a quality check of the area prior to placing the shell. Positioning and sinking the shell should take only a day; however, the underbase grouting required once it is sunk will take approximately 3 weeks for some of the larger sections. Once the shell is placed and the base is securely grouted, the final phase of the float-in construction can begin.

(4) The final phase is the completion of the structure. Tremie concrete will be placed within the shell to form the monolith below the water level. Traditional concrete will be placed above the water level to complete the monolith to its final height.

c. Approach walls. The approach walls will consist of floating, longitudinally post-tensioned, precast concrete boxes called pontoons, which will be anchored to individual drilled-shaft type pylons. The approach wall will be bounded by the lock structure at one end and a nose pier at the other end. The nose piers will be composed of three drilled shafts, a steel shell structure, and concrete infill. The

pontoons are constructed offsite and floated into place. The same type of offsite construction noted in the first stage for the float-in monolith construction will be used to construct the pontoons.

d. Contact. For additional information contact the U.S. Army Corps of Engineers, Louisville District, 600 Dr. Martin Luther King Jr. Place, Louisville, KY 40201.

B-7. McAlpine Lock

a. The construction laydown area at the McAlpine Lock (Figures C-18 and C-19) will be small due to the location of the project within the city of Louisville, Kentucky. Therefore, the use of prefabricated elements that can be constructed offsite and delivered on an as-needed basis has been incorporated into the project as much as possible. These elements include the T-beams for a fixed-access bridge, the walls of a 6-1/2-ft by 3-ft drainage culvert, the slab beams for the deck of a wharf structure, and the facing beams of the approach walls. The use of precast elements in the culvert and baffles of the innovative center longitudinal filling and emptying system of the project is also being considered.

b. The approach walls are provided upstream and downstream of the lock chamber to facilitate alignment of vessels entering and exiting the lock chamber. These walls will be constructed using concrete-filled PS27.5 circular sheet-pile cells founded on bedrock with precast concrete beams spanning between cells to form the approach wall face. This method is similar to the method used for the approach walls at Melvin Price Lock and Dam, Alton, Illinois, and allows the walls to be constructed without erecting a cofferdam. The approach walls will be equipped with standard check posts and line hooks, ladders, handrailing, and a wall armor rubbing surface.

c. An alternate type of approach wall was also allowed in the bid documents. The alternate wall consisted of drilled caisson supports capped by a precast shell beam that was then infilled with concrete. The portion of the wall above water (normal) was cast-in-place concrete. Both options were bid by different contractors. Significant cost savings with the use of the floating wall concept were identified. However, operational problems with grounding clearances and dredging, particular to the site of the McAlpine Lock lower approach, lead to the conclusion that floating approach walls should not be used. Therefore, approach walls consisting of precast beams supported on sheet-pile cells were recommended.

B-8. Upper Mississippi River – Illinois Waterway System Navigation Study (UMR-IWS)

a. Because the existing locks on these two rivers are only 600 ft long but are subjected to heavy river traffic consisting mainly of 1,200-ft-long tows, they cause congestion. The long tows must break into two parts to complete lockage. Adding locks to these existing sites on the Mississippi River that generally have only one lock has been studied since the early 1970's. Alternative locations for placing a second lock at a typical site have included landward of the existing lock, in the existing auxiliary miter gate bay (partial provisions for a second lock from the original construction in the 1930's), through the gated portion of the dam, through the fixed portion of the dam, and along the opposite bank line. Many of these alternatives were addressed in the Upper Mississippi River Navigation Study Reconnaissance Report, 1991 (available from St. Louis District, ATTN: CEMVS-ED-DA). This report considered the use of mostly traditional lock construction techniques, such as within a dewatered cofferdam. It addressed extending the existing lock to 1,200 ft, but determined it to be impractical because of the lengthy lock closure period caused by the cofferdam. The reconnaissance report identified costs of feasible lock locations and alternatives to be in the \$380 million range. In the years following 1991, engineers from HQUSACE, Districts, and Divisions formed a team to investigate innovative lock designs and methods to construct less costly locks. This marked the advent of innovative lock design and construction in the Corps of Engineers. From 1994 to 1996, the Engineering Work Group (EWG) of the UMR-IWS used the results from the innovative lock team as a starting point to develop new lock concepts that were more

economical than traditionally constructed locks. In addition, the EWG determined that it was possible to extend the existing lock despite claims to the contrary in the 1991 Reconnaissance Report. Lock extension concepts developed to ensure feasibility included float-in and lift-in methods of construction. The alternative to extend an existing lock maximizes the reuse of existing features and minimizes costs, estimated to be around \$150 million. The economic costs of delays to navigation during construction were considered based on in-the-wet construction procedures. Constructing most features during the winter months on the Mississippi River, when ice prevents most river traffic from navigating the river, can minimize delay costs. Wintertime construction productivity reductions were considered. This example is included to point out that float-in and lift-in methods of construction can be used to make a project feasible that would otherwise be infeasible, such as the extension of a lock and providing for concurrent navigation traffic.

b. For additional information contact the U.S. Army Corps of Engineers, St. Louis, 1222 Spruce Street, St. Louis, MO, 63103-2833.